A Comparison of the Different Models Used For Interferograms Flattening

ZHANG Yanjie
School of Computer Science and Technology
Yantai University
Yantai, Shandong Province, P.R. China
yanjie.zhang@126.com

***Abstract*—For interferometric SAR (InSAR) processing, the precision of the interferometric phase is very important since it decides directly that of the final measurement. It is known that the interferometric phase is composed of many different parts such as the phase due to the topography, the possible deformation, the atmosphere, the track error and so on. Before doing phase-unwrapping, the interferogram must be flattened to decrease the density of the fringes in the interferogram or it may make phase unwrapping fail. For the practical application of InSAR, if the interferogram is not flattened well, the residual phase due to the earth will be considered to be the phase due to the topography or the deformation. In this paper the different earth reference models that have been used for doing flattening are analyzed. Some experiments have been done on the real images and the conclusions are given at the end.**

I. INTRODUCTION

The application of the InSAR technique is greatly related with the accuracy of the interferometric phase which is decided by the coherence of the images data. When a pair of SAR images is well registered, their phase difference images called interferometric phase or interferogram will show the fringes which are related with the information of the topography on the earth. It is known that the interferometric phase is composed of many different parts such as the phase due to the topography ϕ_{topo}, the flat earth ϕ_{earth}, the possible deformation ϕ_{def}, the atmosphere ϕ_{atm}, the track error ϕ_{track} and so on [2].

$$\phi = \phi_{topo} + \phi_{earth} + \phi_{atm} + \phi_{def} + \phi_{track} + \phi_{noise} \tag{1}$$

If it is not done properly, the phase due to the manually processing will be introduced into the final inteferometric phase. It has been shown that the precision of the interferometric phase decides directly that of the final measurements. Though the quality of the interferogram suffers mainly from the coherence of the data, the method selected for interferogram processing is also very important. A good interferogram generation method will greatly reduce the effect due to the manually processing.

According to the InSAR imaging geometry, the raw interferogram can't avoid the flat earth effect that means the phase difference created due to the non-zero baseline. Because of the existence of the flat earth effect, the objects with the same height on the ground don't have the same interferometric phase. Furthermore the flat earth effect makes the density of the fringes in the interferogram very high, and it adds more difficulty for the vital phase-unwrapping processing. So before doing phase-unwrapping, the interferograms must be flattened. At the mean time, after doing flattening the interferogram will look like the contour image of the topography.

II. PROBLEM ANALYSIS

The flat-earth removal methods can be categorized into two classes: using the parameters of the orbit and dealing with the interferograms directly. The problem with the first method is the uncertainty of the orbit parameters will have an effect on the positioning accuracy. The second method is mainly realized by estimating the position of the maximum frequency in the interferogram spectrum where the regular flat earth phase will dominate. Then the reference phase can be removed. But this kind of method suffers from the noise due to the low coherence of the data. For those low coherent SAR images data especially those that have long time baseline, this kind of problem is very seriously. The flattening results depend greatly on the maximum estimation accuracy.
The orbit parameters based interferogram flattening methods are mainly using the flat earth model or the elliptical earth model.

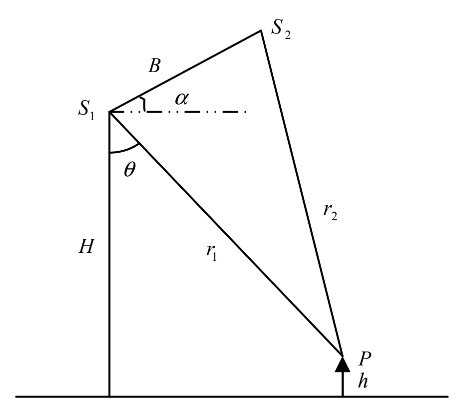

Figure 1. Flat earth based flattening model

Fig-1 illustrates the flattening method using the flat earth model, where B is the baseline, θ is the incidence angel, α is the tilt angel, r_1 and r_2 are the distance between the satellite and the object on the earth, H is the height of the satellite and h is the height of the object on the earth. The flat

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **25 JUL 2005**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **A Comparison of the Different Models Used For Interferograms Flattening**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **School of Computer Science and Technology Yantai University Yantai, Shandong Province, P.R. China**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM001850, 2005 IEEE International Geoscience and Remote Sensing Symposium Proceedings (25th) (IGARSS 2005) Held in Seoul, Korea on 25-29 July 2005. , The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**3**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

earth phase can be calculated using (2).

$$\phi_{earth} = \frac{4\pi}{\lambda}(r_1 - r_2) = \frac{4\pi}{\lambda} B\sin(\theta - \alpha) \qquad (2)$$

While for the flat earth model, it is easy to know $\sin\theta$ and $\cos\theta$ by equ (3)

$$\sin\theta = \sqrt{1 - \frac{(H-h)^2}{r_1^2}}\ ,\quad \cos\theta = \frac{H-h}{r_1} \qquad (3)$$

Then ϕ_{earth} can be rewritten as:

$$\phi_{earth} = \frac{4\pi}{\lambda} B\left(\cos\alpha\sqrt{1 - \frac{H^2}{r_1^2}} - \sin\alpha\frac{H}{r_1}\right) \qquad (4)$$

For the elliptical earth based flattening method, before doing flattening, the position of each pixel in the image has to be calculated using the method proposed by [1]. Because the satellite coordinate can be calculated using the orbit data, it is easy to calculate the flat earth or reference phase ϕ_{earth} .

$$\phi_{earth} = \frac{4\pi}{\lambda}(r_1 - r_2) \qquad (5)$$

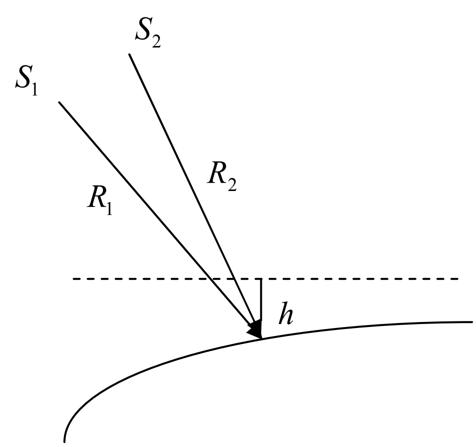

Figure 2. Elliptical earth based flattening model

The flat earth effect can be removed point wisely. But it will cost much more time when the image size is very large. In order to save time a polynomial can be used to fit the reference phase ϕ_{earth} . It should be a function of the pixel coordinate (row, column), which means it changes both in range direction and in azimuth direction.
From fig-3 it is easy to get (6).

$$\Delta\theta = \frac{h}{R_1 \sin\theta}\ ,\quad h << R_1 \ \&\ R_2 \qquad (6)$$

Let $\Delta = \theta - \alpha$, then

$$B\sin(\Delta + \Delta\theta) = B\sin\Delta\cos\Delta\theta + B\cos\Delta\sin\Delta\theta \qquad (7)$$

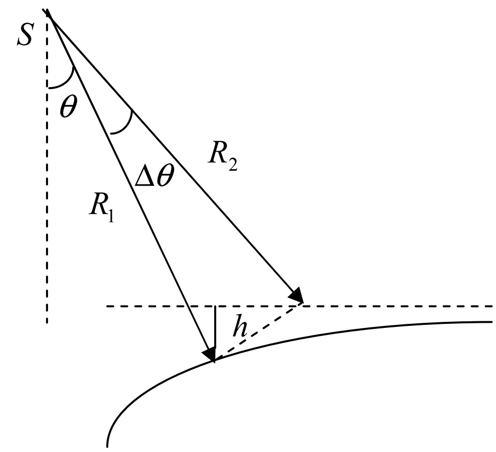

Figure 3. Combination of flat earth and elliptical earth model

Because $\cos\Delta\theta \approx 1$ and $\sin\Delta\theta \approx \Delta\theta$, equ (7) is equal to equ (8)

$$B\sin(\Delta + \Delta\theta) = B\sin\Delta + B\cos\Delta\frac{h}{R_1 \sin\theta} \qquad (8)$$

From (8), the phase difference ϕ_{diff} due to the application of different earth reference model is:

$$\phi_{diff} = \frac{4\pi}{\lambda} B\cos(\theta - \alpha)\frac{h}{R_1 \sin\theta} \qquad (9)$$

The phase difference ϕ_{diff} can be related with the registration error p_{diff} by (10), where R_s is the slant range resolution.

$$p_{diff} = B\cos(\theta - \alpha)\frac{h}{R_1 R_s \sin\theta} \qquad (10)$$

CONCLUSIONS

For the different earth reference models that have used to do interferogram flattening, the computation load is a little different. While the selection of the reference earth model will depend on the flying height, the size of the imaging area and the incidence angel of the synthetic aperture radar. The flat earth model based flattening model will run the risk of decreasing the SAR images fine registration precision which will have an impact on the coherence of the data.

REFERENCES

[1] Curlander, J. C., "Location of Spaceborne SAR Imagery", IEEE Transactions On Geosciences and Remote Sensing, Vol. GE-20, No. 3, July, 1982..

[2] Ramon F. Hanssen, Radar Interferometry-Data Interpretation and Error Analysis, Kluwer Academic Publishers, 2001..

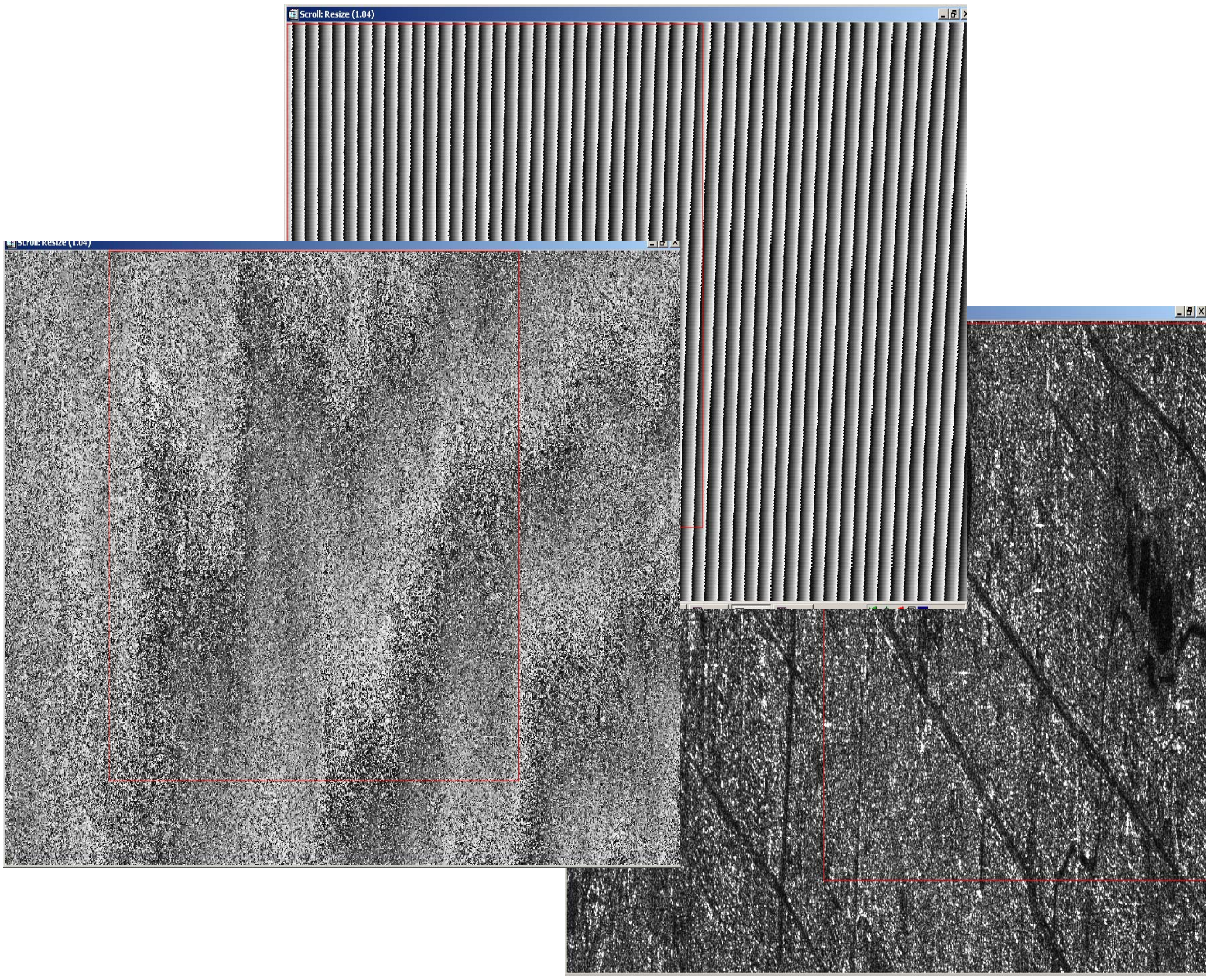

Figure 4. Flattening results using Beijing area ERS－2 May 20th ,1998 and Jun 24th , 1998 (bottom : amplitude image; middele: polynomial fitted reference phase; top: flattening result based on elliptical model)